Advanced Propulsion For Tactical Missiles

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Armaments for the Army Transformation

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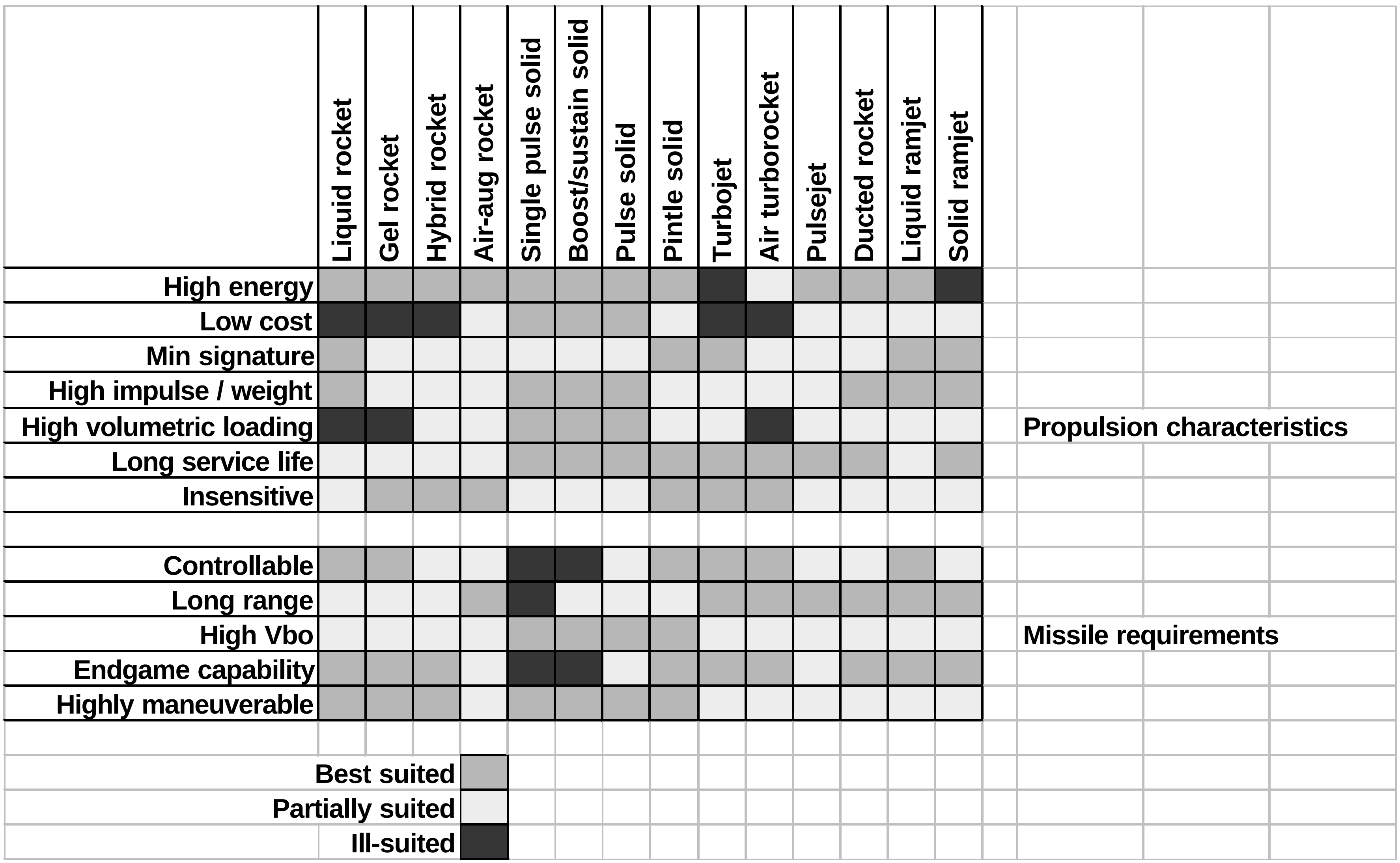
Propulsion and Structures Directorate

AMCOM

User Requirements

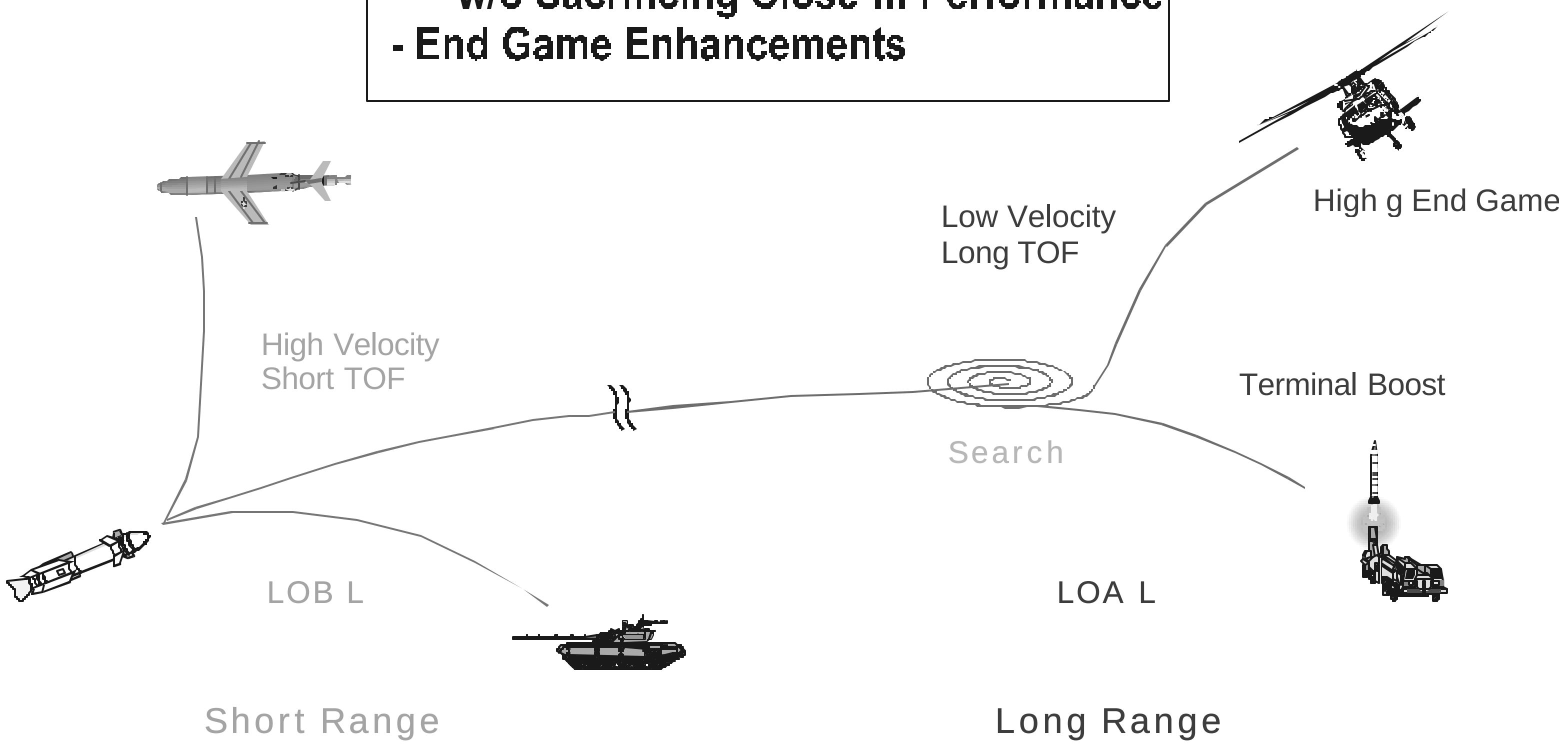
- Low operating and support costs
- Controllability
- Advanced materials
- Minimum signature
- High energy
- Insensitivity
- Minimal toxicity
- Long life
- High reliability

Propulsion Cycles

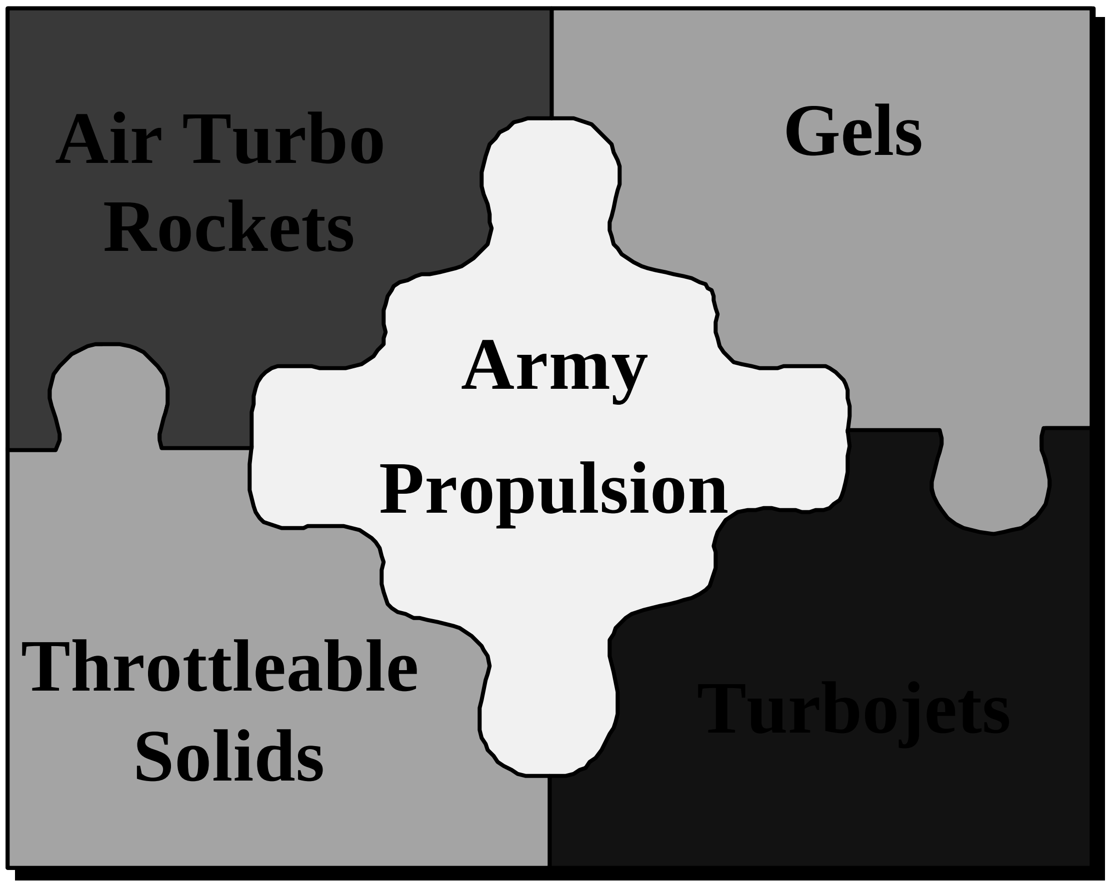


Advantages of Controlled Thrust Propulsion Systems

- Multiple Target Sets
- >3x Range Improvement
  w/o Sacrificing Close-in Performance
- End Game Enhancements

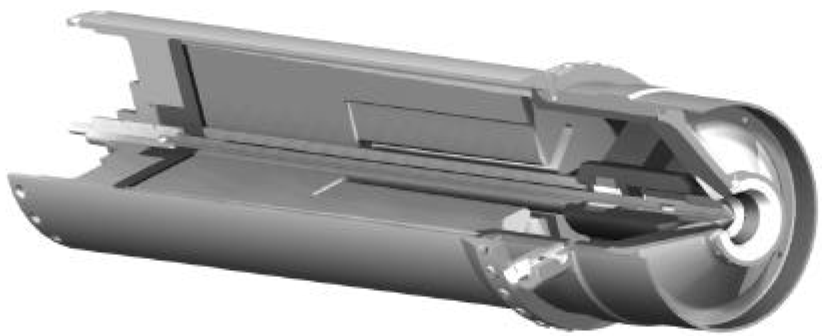


Approach


Air Turbo Rockets
Gels
Army Propulsion
Throttleable Solids
Turbojets

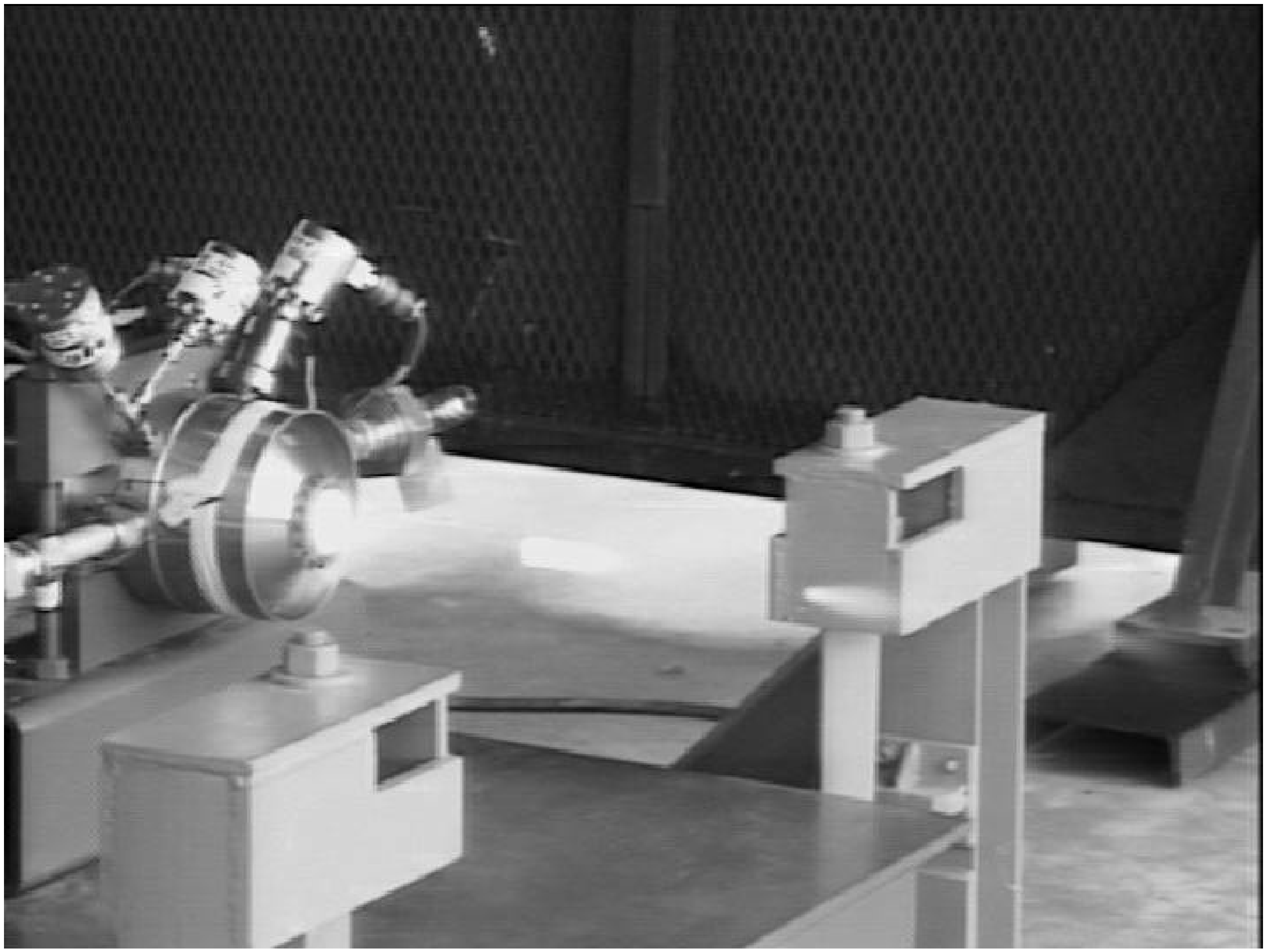
Variable-area Nozzles

- 20:1 turn down
- Up to 12” diameter
- Axial and off-axis actuation

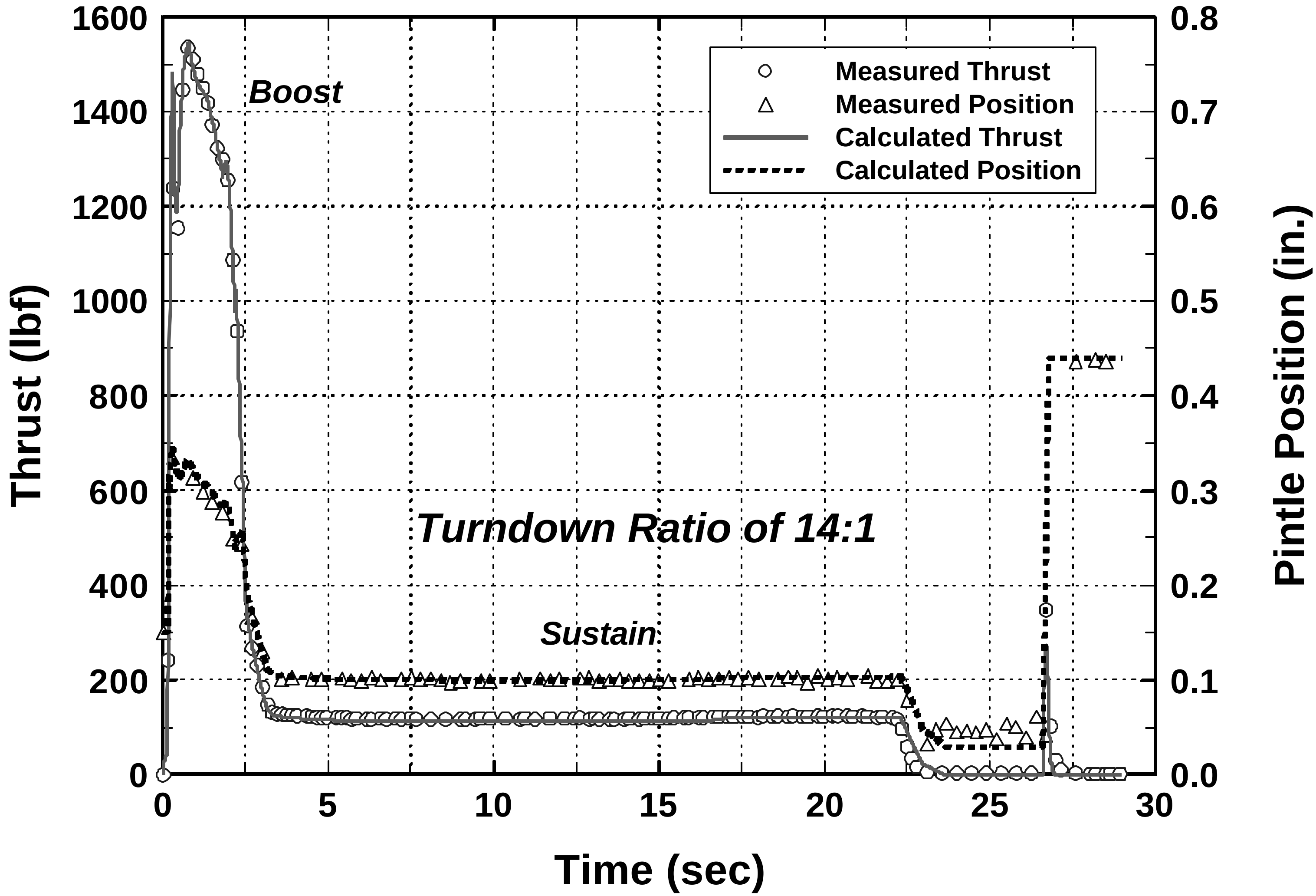


- CFD modeling of pintle shapes
- Evaluation of pintle materials

Variable Thrust Motor Static Firing
Test #1

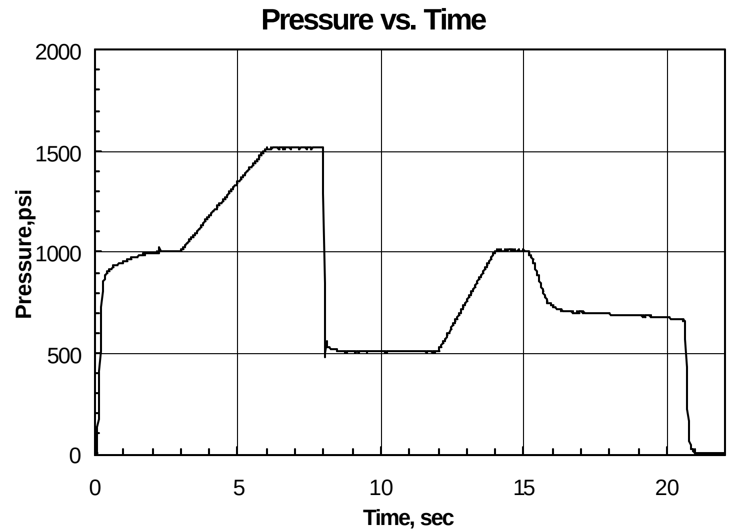


VTM Test # 2 Results
Thrust and Pintle Position



Pintle Controlled Solid Technology

- Controllable, variable thrust propulsion
- Tactical boost/sustain/coast profile with high thrust turndown ratio
- Ability of pintle to control pressure and thrust within 2% of desired value
- Motor response times acceptable for tactical applications
- AMCOM-developed AN minimum smoke propellant



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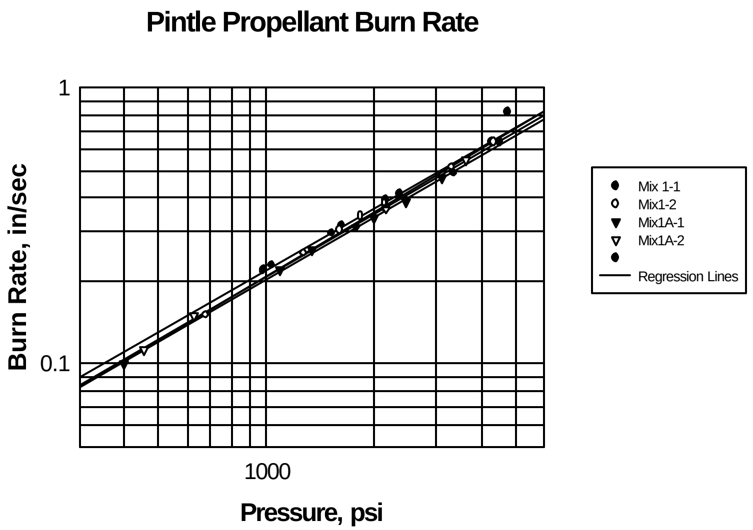
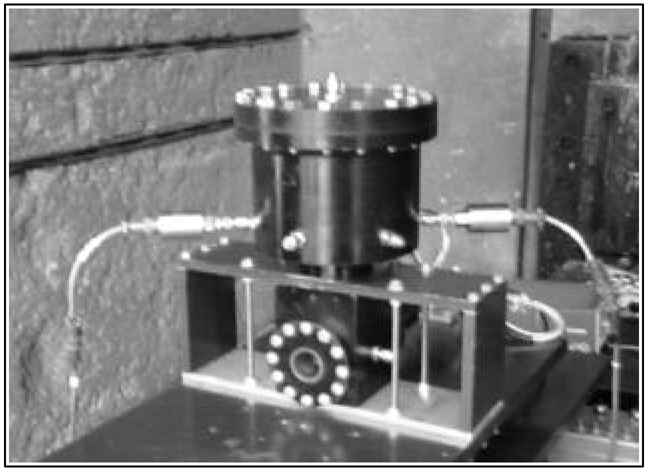
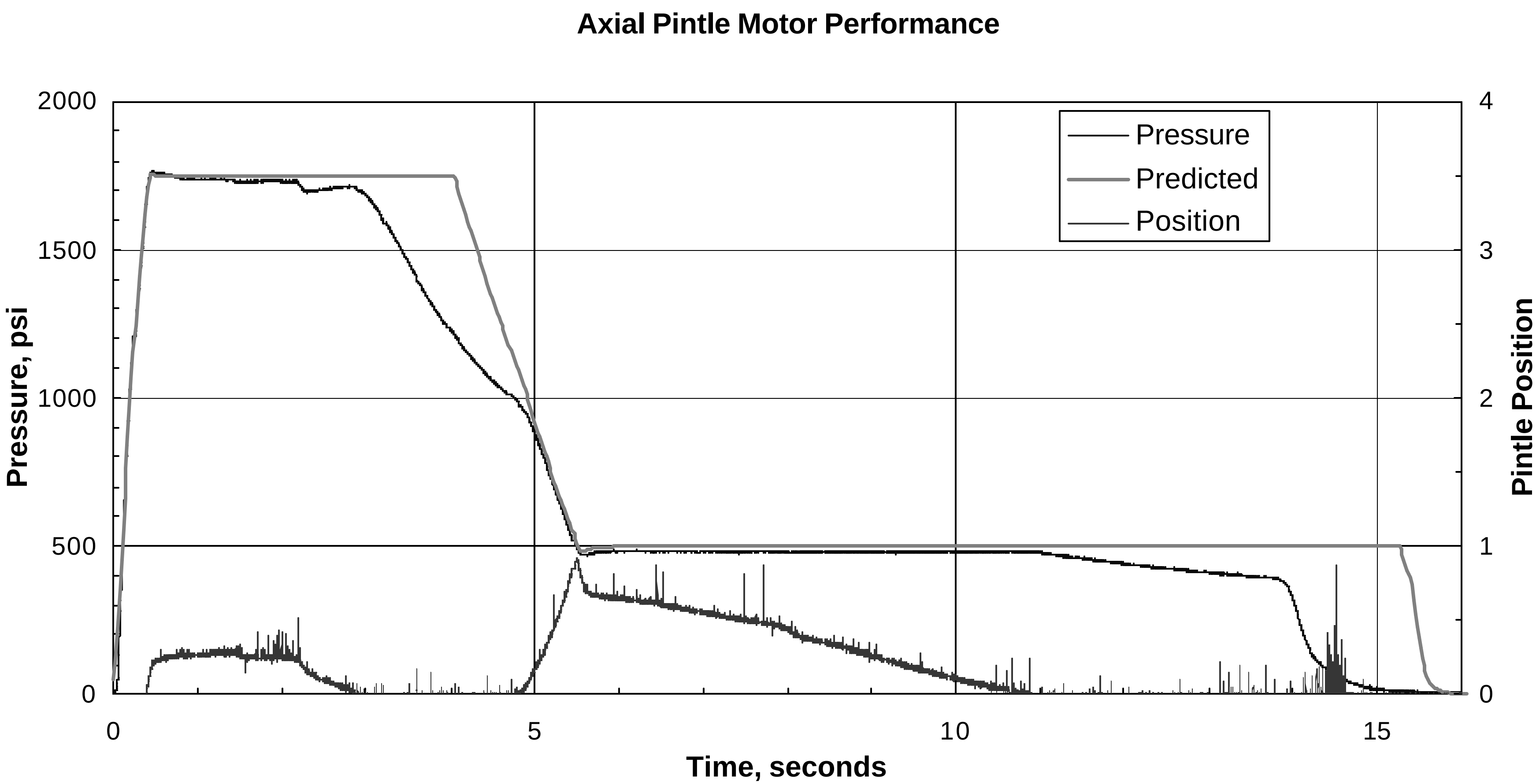


Non-Axial Heavywall Hardware

6 Inch Diameter Motor



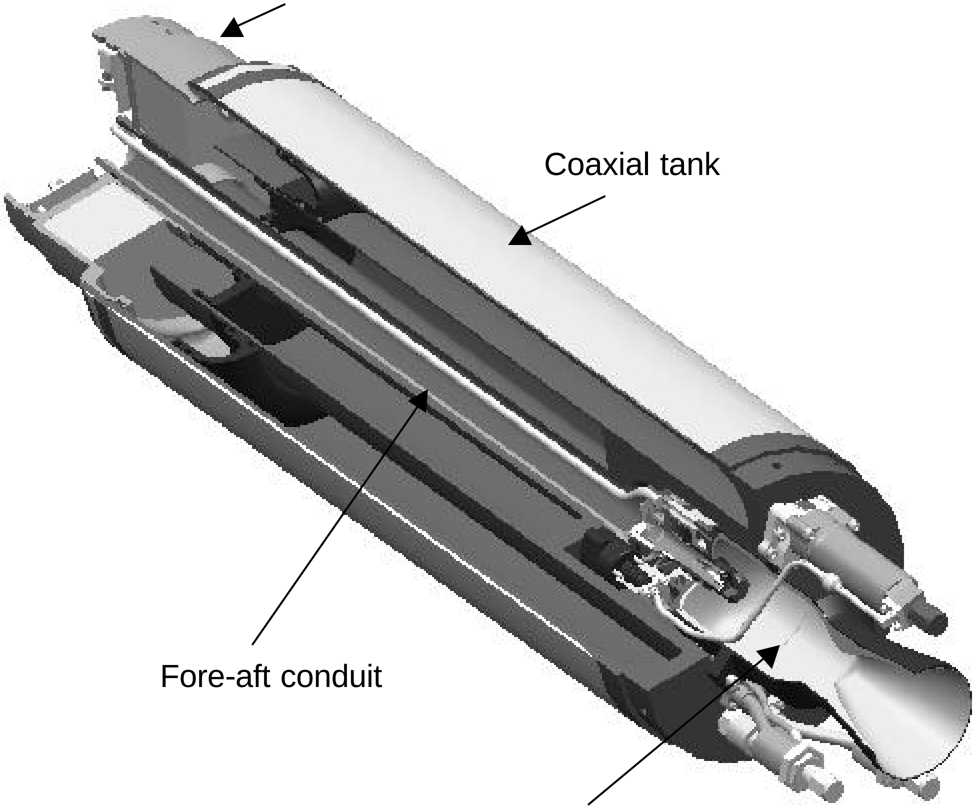
“Self-healing” Properties



Gel bi-propulsion systems

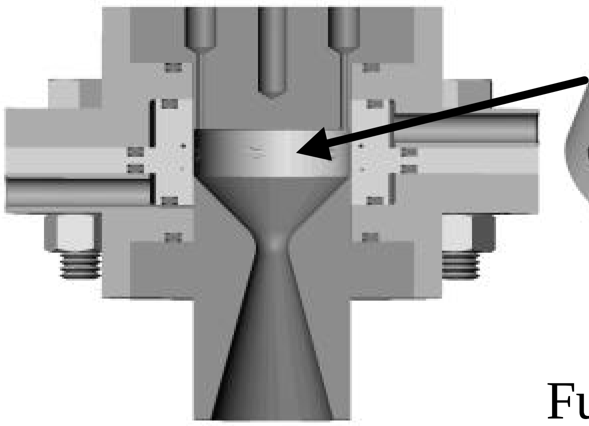
- have controlled thrust
  - Minimize time to target ; Maximize range
  - Provide a variety of thrust profiles to perform multiple missions; end-game enhancements
- are rugged and reliable
  - Demonstrated ruggedness by withstanding two hard landings with no evidence of leaks
- are survivable
  - Have plumes with minimum signature exhaust
  - Meet Insensitive Munitions requirements
  - Have gel propellants that:
    - Are immobilized at ambient conditions
    - Have greatly reduced vapor pressure

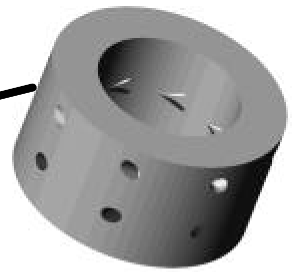
FMTI Gel Propulsion System



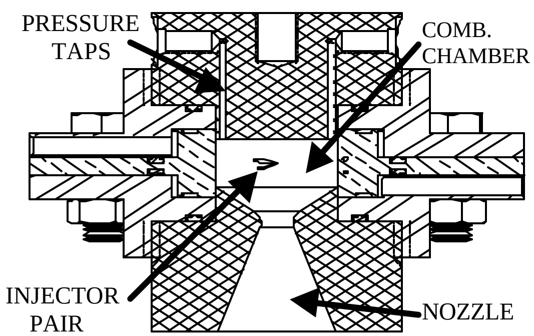
- Key Features
  - Fits in TOW envelope w/greater than 2X TOW range
  - Retains short time-of-flight for close-in targets
  - On-demand, unlimited duty cycle, multi-pulse motor for velocity control
  - Central conduit for missile fore-aft cabling and wave guide
  - Can easily be sized for other missile systems (Common Missile, Modernized Hellfire, etc.)

The AMCOM Impinging Stream Vortex Engine (ISVE)





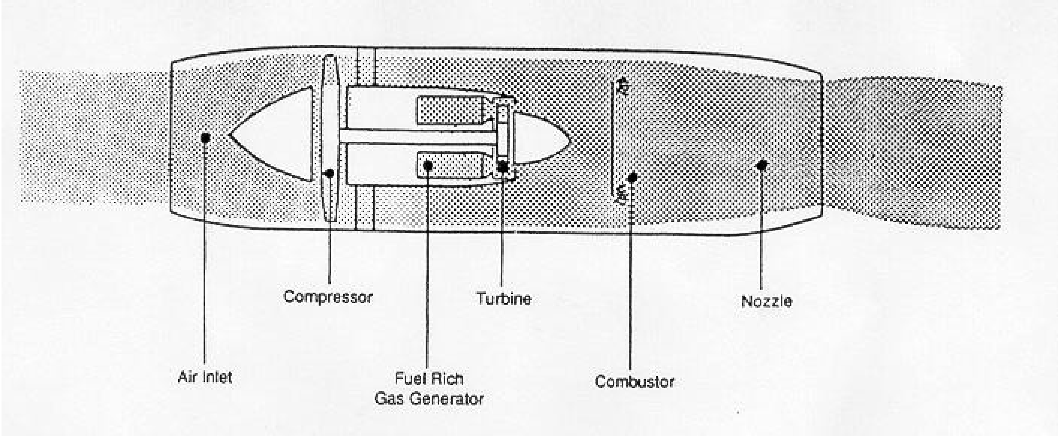
The ISVE was developed in AMCOM. The original patent was awarded in 1968 while the modern concept (shown here) was patented in 1997 by AMCOM and is currently undergoing test/evaluation in the Propulsion/Structures Directorate at AMRDEC (Redstone).



Fuel and oxidizer are injected through pairs of injector holes placed along the chamber wall. Within a pair, these holes are slanted toward each other (the fuel/oxidizer streams impinge) and azimuthally so that vortical mixing is induced along the chamber wall. Impingement angles are set such that the vertical component of the stream momentum vector is zero. The wall is transpiration cooled by the flow. This mixing has been shown to be beneficial for liquid and gelled propellants.

Benefits: Simple design allows for low cost hardware. For length constrained systems, small L/D for the combustion chamber means more engine length for flow expansion. Stream impingement enhances atomization of gel propellant.

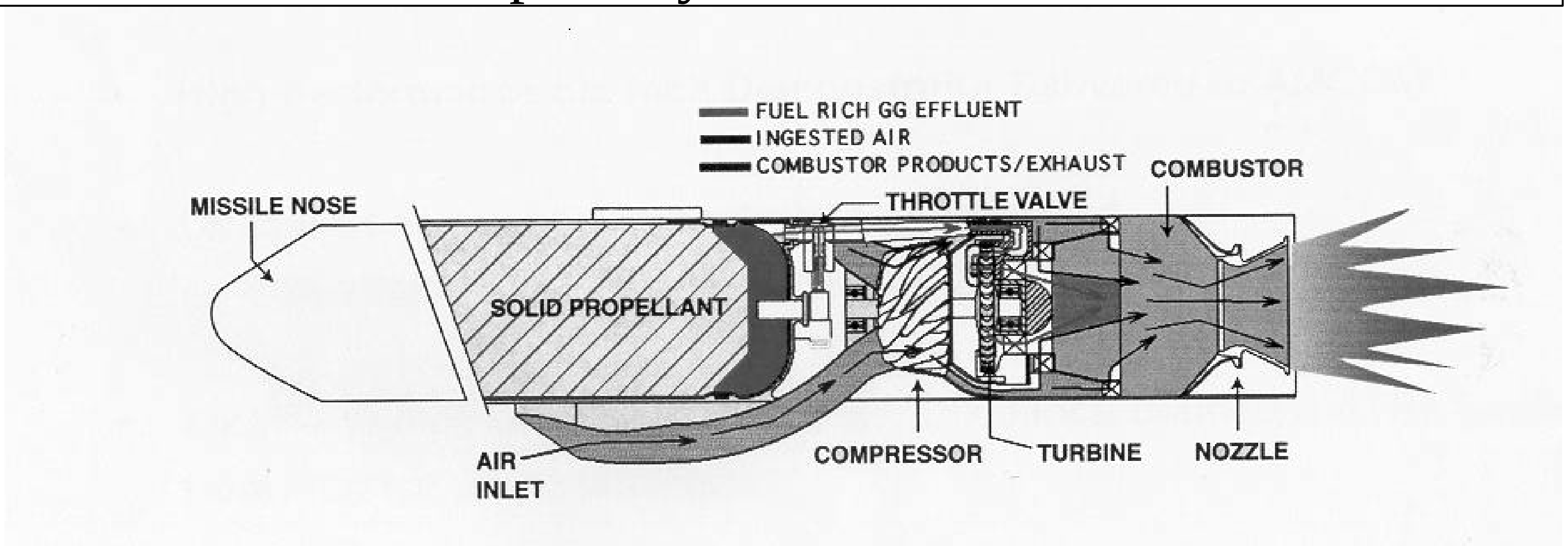
ATR General Description



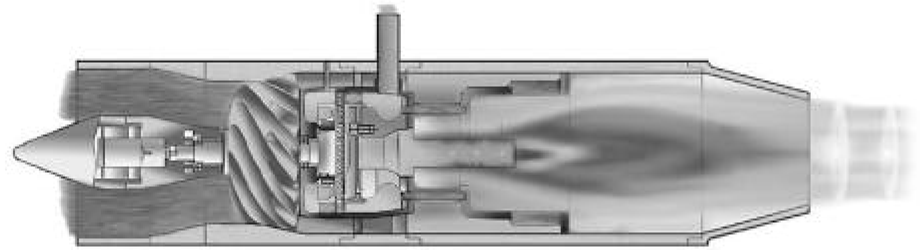
- Utilizes a compressor and turbine, similar to a turbojet or turbofan
- Also utilizes a secondary combustor much like a ramjet or ducted rocket
- The turbine and compressor are linked by a mechanical drive shaft
  - turbine power from the gas generator fuel effluent drives the compressor

Typical ATR Scheme

- Turbine drive gas:
  - Independent of compressor airflow
  - May be generated by a hot gas source
    - a liquid or solid propellant gas generator
  - Utilized as the primary fuel source



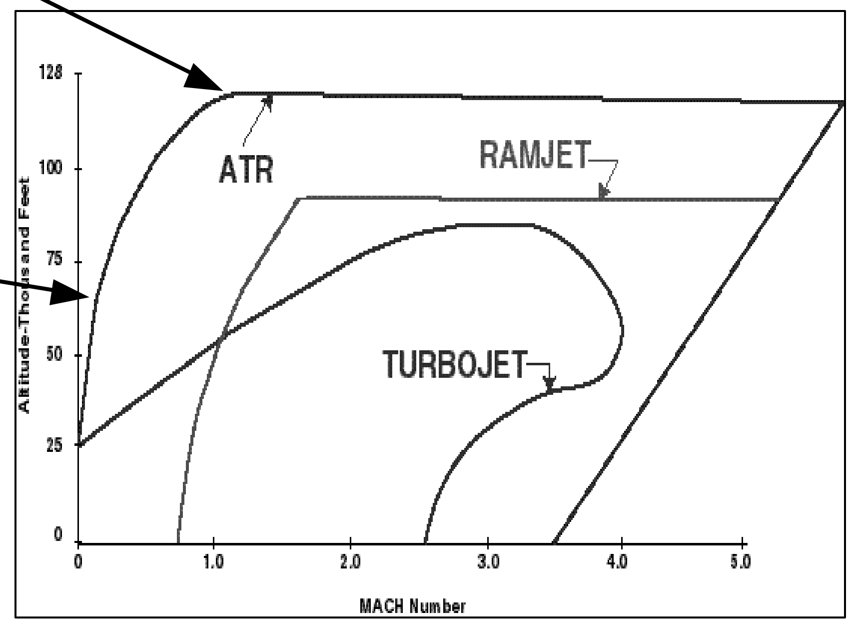
Air Breathing Turbo-Rocket



- Independent Drive for Turbine Gives Higher Speed and Altitude Capability

- Static Thrust Allows Low Speed Takeoff

- Deep Throttleability Allows Loiter Capability Combined With High Speed Intercept



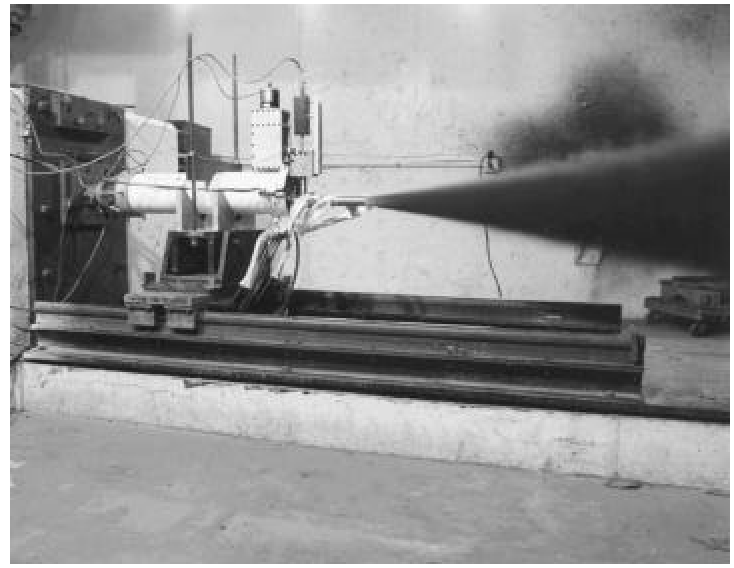
Fits Directly Between Turbojets And Rockets Without Extreme Technology Challenges

ATR Cycle Advantages

- Maximum speed superior to either a turbojet or turbofan
- Compressor inlet temperature is the limiting component parameter in an ATR
  – The compressor inlet temperature determines the maximum flight speed for any given altitude
  – No rotating hardware in the hot section
- The ATR does not require a separate booster
  – Easily operates at low flight speeds at which a ramjet or ducted rocket cannot operate
  – Performs well at sea level static conditions
  – High thrust per frontal area
  – High turn down ratio --- >10:1

ATR Design Challenges

- Most existing solid propellant gas generators are not optimized for use in an ATR
- A suitable gas generator effluent must be:
  - An effective secondary combustor fuel
    - Should maximize residual heating value
    - Retain excellent combustion properties
  - An efficient turbine drive gas should have low molecular weight
- ATR secondary combustion chamber design is critical
  - To maximize the operational performance of the cycle requires:
    - Short residence time
    - Must combust a potentially fuel rich equivalence ratio
    - Operate at low combustion pressures

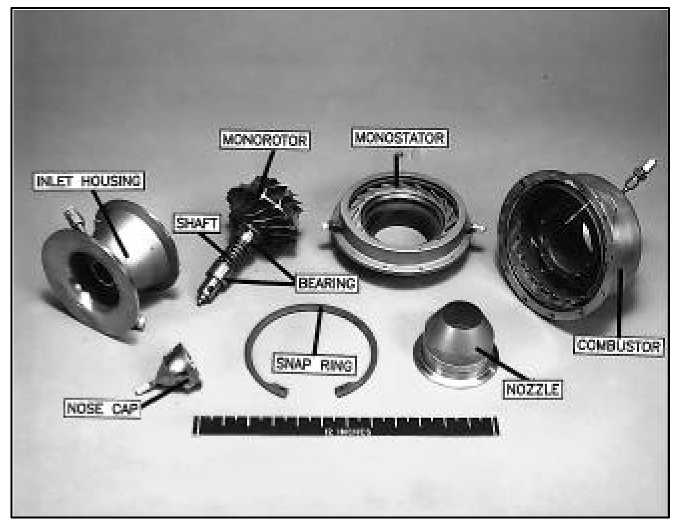


DARPA/AMCOM Key Sponsors Of Small Engine Development

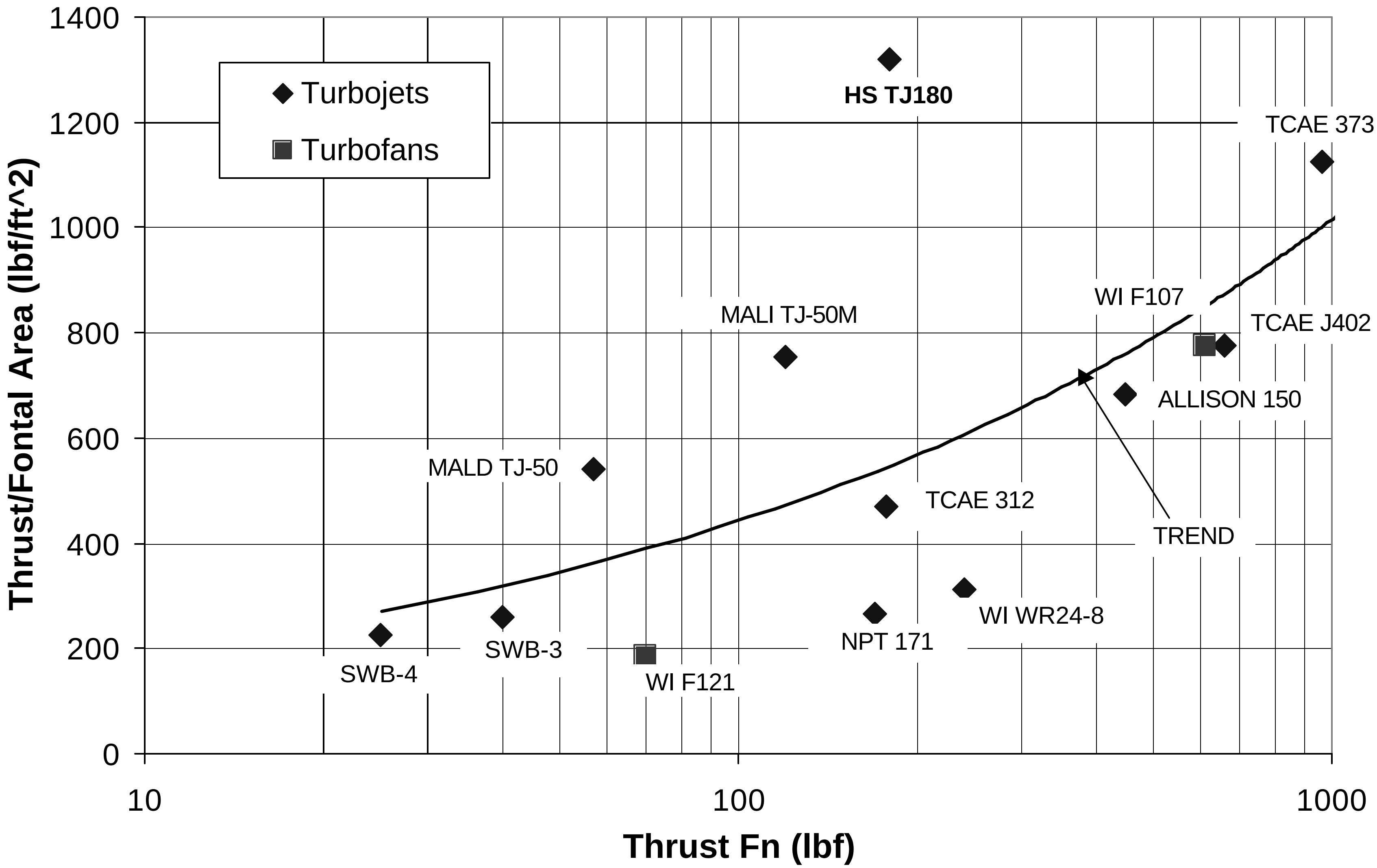
Year	Engine	Thrust	Program	Flight Test
1985	*TJ-20*	*40 - 70 lb*	*US Army MICOM MIG-29 Target*	✓
1989	*TJ-90*	*105 lb*	*US Army MICOM FOG-M Risk Reduction*	
1990	*TJ-50*	*50 lb*	*DARPA SENGAP Four Inch Engine*	
1994	*TJ-50-1*	*50 lb*	*DARPA/Northrop MALD POC*	✓
1996	*TJ-50-3*	*50 lb*	*Teledyne Ryan MALD POC*	✓
1996	*TJ-50-10*	*57 lb*	*DARPA/Ryan MALD ACTD*	✓
1997	*TJ-65*	*80 lb*	*DARPA Advanced Material Partnership*	
1999	*TJ-50-11*	*52 lb*	*US Army AMCOM PKAT Missile*	
1999	*TJ-50M-1*	*120 lb*	*DARPA/Ryan MALI ATD*	✓
2000	*TJ-30*	*30 lb*	*DARPA NetFires*	✓

Technology Goals and Tasks

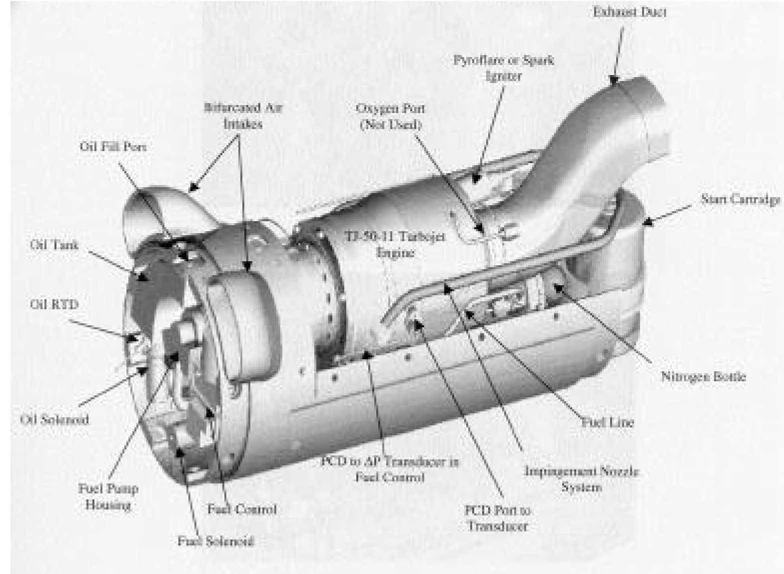
- Advantages of Airbreathing Propulsion
  - Propulsion flexibility and multi-mission capability
  - Supports AMCOM missile systems
  - Very low fuel consumption
  - Benefits from advanced sensor and system technologies
- Target goals
  - low cost
  - expendable (<15 minutes operation)
  - minimum of parts and hardware
  - microprocessor based components



Expendable Turbojet/Turbofan Performance Comparison

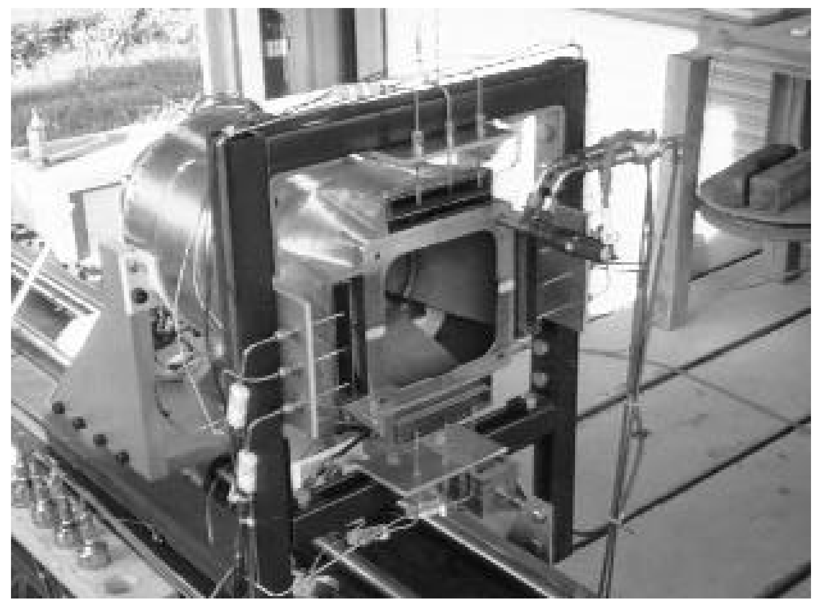


Allison 150 Fore & Aft



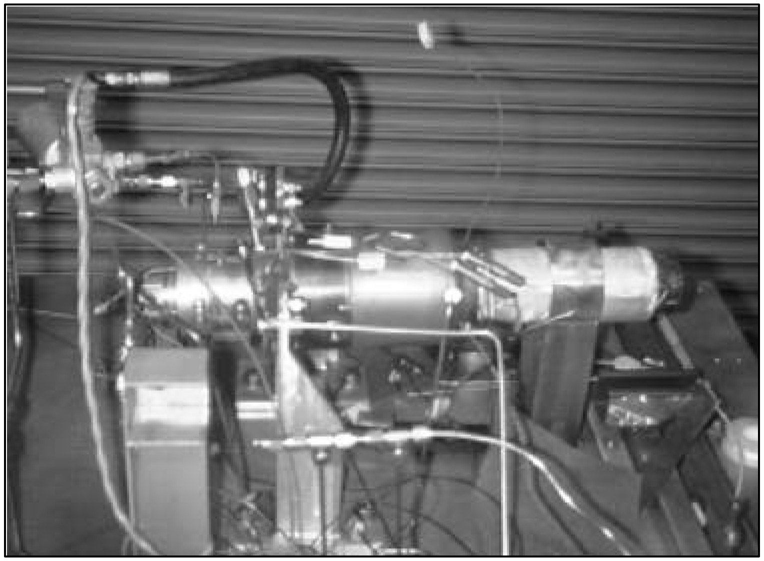
View into Compressor

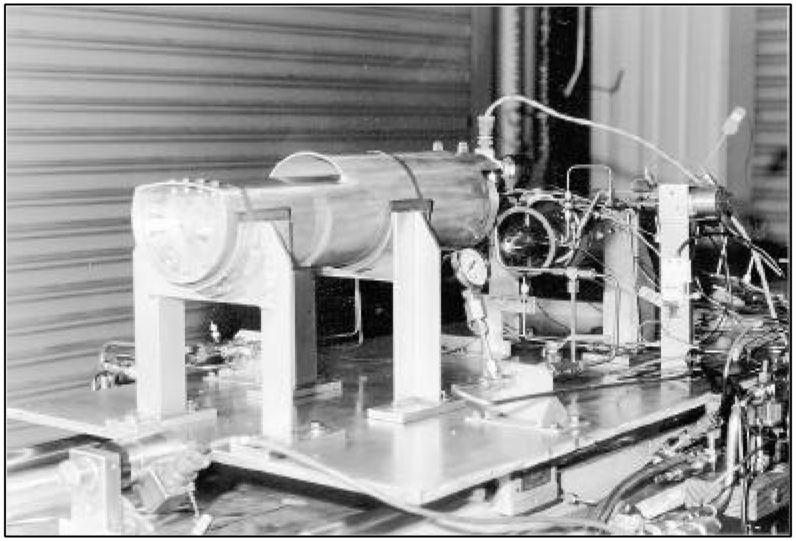
Quad Exhaust View



Small 4.0 Inch Turbojet

- Sunstrand TJ-50
  - Successfully flown in flight tests
- 50 lbs thrust, <10 lbs weight
- Simple design, no exotic materials
- Engine Speed: 135,000 RPM





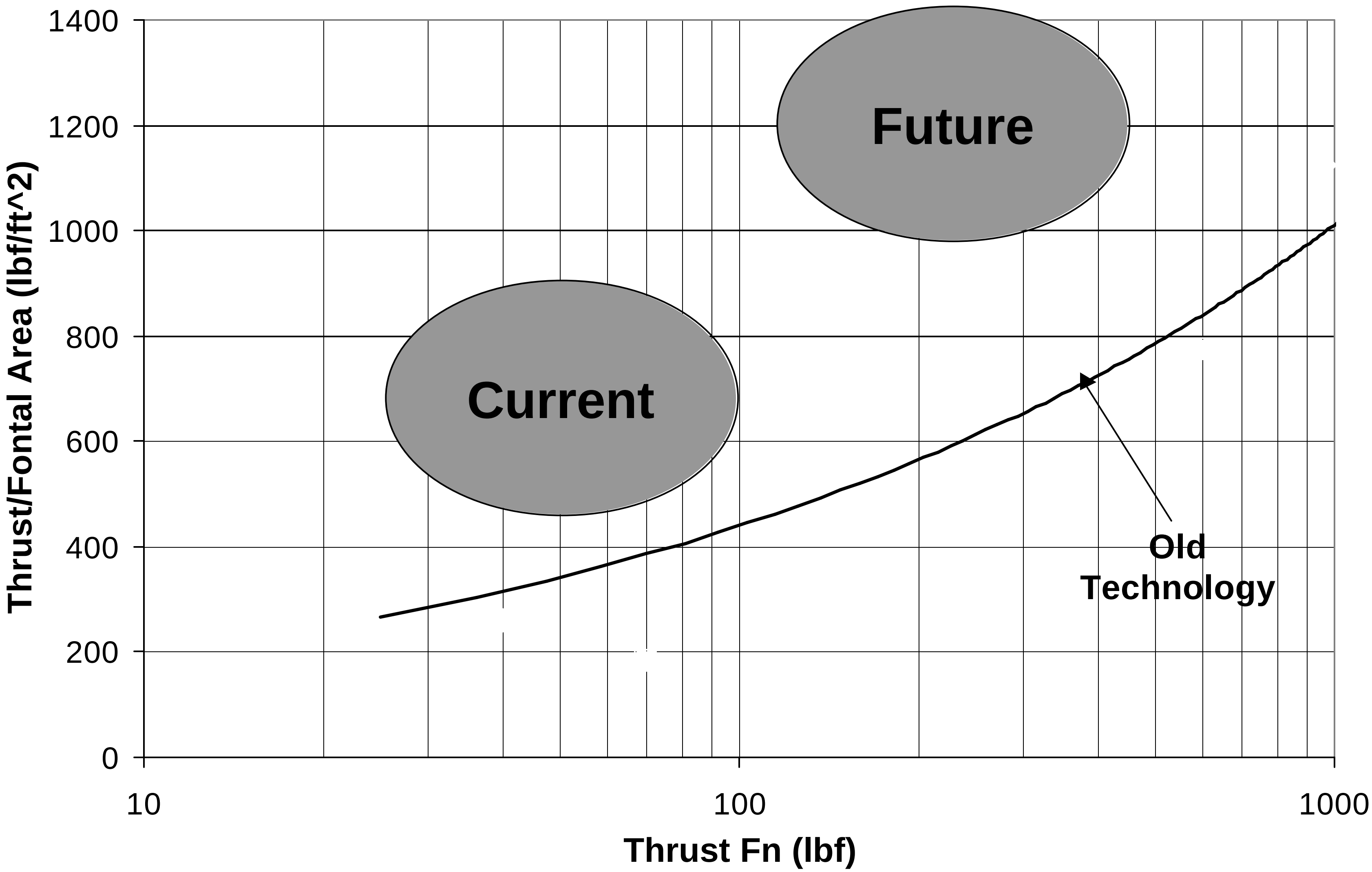
Key Technologies For Small Turbojets/Turbofans

- Very Small Combustors
  - Much higher heat loading than larger engines
  - Altitude starting
- Small Diameter Compressors
  - High efficiency aerodynamics in small sizes
  - Mixed flow for small diameter
- High Speed Bearings
  - >130,000 RPM

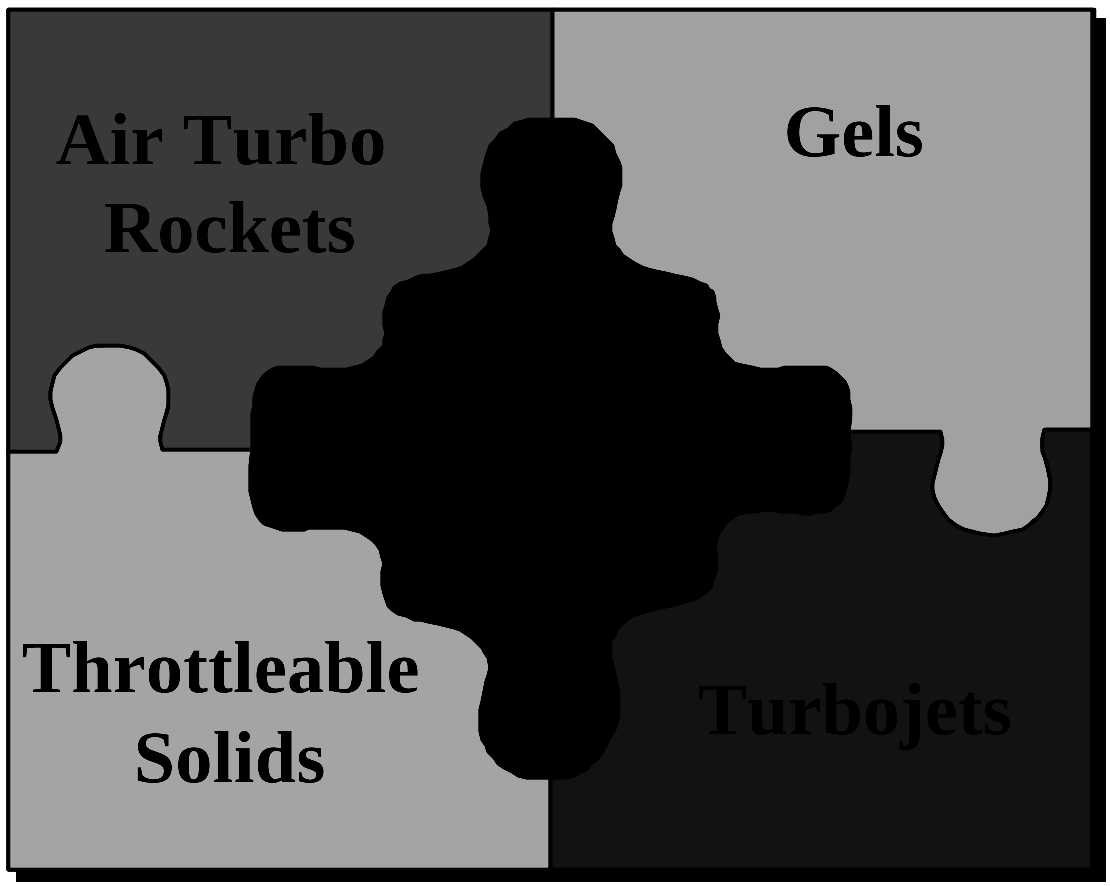
Availability of these technologies has given great improvement in the major vehicle parameter -

THRUST PER UNIT FRONTAL AREA

Technology Path

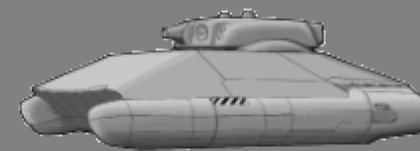
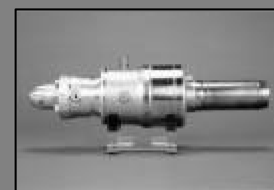
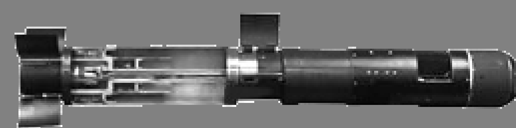


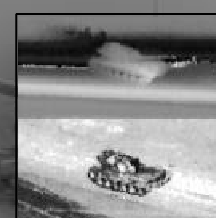
Summary



End products

- Smarter
- Smaller
- Lighter
- More Lethal
- More Autonomous
- AFFORDABLE

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